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Review

The Evolution and Future Prospects of China's Wave Energy Policy from the Perspective of Renewable Energy: Facing Problems, Governance Optimization and Effectiveness Logic

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Abstract: Wave energy is a kind of new marine renewable energy with broad development prospects. Many countries have launched aggressive public policies to promote the use of wave-energy technology. In this paper, 729 wave-energy policy documents were visually analyzed by Citespace software, and 31 Chinese wave-energy policy documents were visually analyzed by Nvivo software. It was found that, on the one hand, wave-energy policy research presents an upward trend. Compared with foreign wave-energy policy research, the research foundation of China's wave-energy policy is weak, the research is not in-depth enough, and the research enthusiasm is not high. On the other hand, China's wave-energy policy is gradually improving, showing a development trend from extensive to detailed, with diversified policy tools and specific policy objectives, although there is still room for improvement.

Keywords: wave-energy policy; wave energy; renewable energy; clean energy

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1. Introduction

The global climate problem is becoming increasingly serious, and countries attach much importance to clean-energy production [1]. As an important part of marine energy, wave energy has nearly 32,500 TWh/y of development space [2], and wave energy has been developed and utilized internationally as a strategic renewable resource. According to the International Renewable Energy Agency (IRENA), the global installed capacity of ocean energy is expected to rapidly increase to 3.0 GW in the next five years, reaching 70 GW and 350 GW in 2030 and 2050, respectively. According to China's State-owned Assets Administration Commission of The State Council, China's semi-submersible aquaculture platform, using wave energy and solar-power generation has been transferred to the commercial operation stage [3]. Construction of two sets of 500 kW wave-energy power-generation units has been completed and entered the sea-trial stage [4]. Megawatt-class floating wave-energy power-generation units have entered the assembly stage [5]. From the research and development of marine-energy power-generation technology to grid-connected power generation, China has become one of the few countries in the world that has mastered the large-scale development and utilization of marine-energy technology [6,7].

Development of the wave-energy industry is a complex and challenging national strategic goal that must be supported by a comprehensive policy framework [8]. Countries with advanced wave-energy technology, such as Australia [9,10], the United Kingdom [11,12], the United States [13], etc., have accumulated a large amount of policy experience in mechanism technology [10], resource assessment [14–16], reductions in development costs [17], stable power generation [18], and optimization of conversion devices [19,20]. As a rising star, China's wave-energy policy is also constantly expanding and improving. Since 2006, China has explicitly included wave energy in the National Marine Renewable Energy System in the Renewable Energy Law of the People's Republic of China. In recent years, the 14th Five-Year Plan for Renewable Energy Development, the Action Plan for Peaking Carbon Emissions before 2030, the Interim Measures for the Management of Special Funds for Marine Renewable Energy, and related policies have been intensively promulgated, indicating that China has established an initial wave-energy policy system. However, compared with countries with advanced wave-energy technology, China's wave-energy policy system is not perfect, the policy content is slightly weak, the policy objectives are not clear enough, and the coordination of institutional management is poor. Building a sustainable and stable policy system is of great strategic significance to promote the development of the wave-energy industry and enhance the core competitiveness of marine renewable energy [21].

Many scholars have made many contributions in the field of renewable-energy policy analysis. For example, Iskandarova used actor-network theory to evaluate the effect of wave-energy policy [12]. Dalton found that whether wave-energy strategy can be successfully promoted is closely related to targeted policies. Effective policies can stimulate innovation in technology development and promote the manufacturing of equipment production [22]. Qiu summarized China's policies and projects in the field of marine renewable energy and identified China's achievements in the field of wave energy [6]. Liu compared the policies of the United Kingdom, Portugal, the United States, and China on the assessment and exploitation of wave-energy resources, summarized the main factors affecting the development of the marine energy industry, and put forward some suggestions on the exploitation of wave energy [11]. There has not been a systematic review and comparative analysis of Chinese and international studies on wave-energy policy.

Based on this, this paper intends to visually analyze the research results of wave-energy policy and China's wave-energy policy, and depict the policy-research hotspots, the changes in wave-energy policy themes, and the sustainability of wave-energy policies through time-series analysis. Through visual analysis, the article plays the role of the following three aspects. First, the article reveals the origin, direction, and development of the keywords of wave-energy policy. Secondly, the correlation characteristics and transmission mechanism of each element of wave-energy policy text are evaluated. Thirdly, the paper grasps the law and trend of wave-energy policy evolution. Through the visual analysis of policy texts, the core elements and goal shifts in China's wave-energy policy are judged so that wave-energy policymakers can clearly understand the advantages and disadvantages of China's policies and the policies of advanced Western countries, and provide a reference for the future construction of China's wave-energy policy system [23].

2. Materials and Methods

2.1. The Data Source

2.1.1. Academic Literature Retrieval

This paper selected the CNKI database and Web of Science (WOS) core-collection database as data sources; the retrieval date was 13 October 2022. The specific retrieval steps were as follows: In the advanced search function of CNKI, 39 Chinese papers from 1992 to 2022 were retrieved using "subject = wave energy" and "subject = policy," "document type = journal," "journal source = all," and "no time span" as search conditions. Excluding news, conference notices, policies and regulations, summary reports, and other irrelevant literature, 35 papers were obtained as the literature samples for the CNKI econometric analysis. The literature search with "TS = 'wave energy' or 'wave power'" and "database = 'core collection of Web of Science'" in the WOS database retrieved over 290,000 results. In the current search results, the data were refined according to "subject = policy," "article type = ARTICLE&REVIEW," "database = WOS core collection," and "language = ENGLISH," and 694 articles were obtained as literature samples for a quantitative analysis of the WOS core-set database. The authors were not restricted in the search process of the WOS database. In other words, the search results included all published research results of authors related to wave-energy policy, regardless of the nationality of the authors.

2.1.2. Policy-Text Retrieval

Policy texts can be retrieved from official websites of major government agencies, such as the website of the Government of China, the official website of the National Development and Reform Commission, the official website of the Ministry of Ecology and Environment, and the official website of the Ministry of Natural Resources, and databases of policy texts, such as the magic weapon of Peking University and other important journals. After sorting out by author, a total of 31 wave-energy policy documents was retrieved.

2.2. Research Methods

This paper used the bibliometric method and content-analysis method to carry out its analysis. At present, Citespace and Nvivo software are commonly used in text analysis, bibliometrics, and atlas rendering. In this paper, Citespace6.1.R3, the latest version, was selected to visually analyze the sample files retrieved from the CNKI database and WOS core-set database [24–26]. The knowledge map drawn by the software can show the research history, current situation, hotspots, and cutting-edge issues in the field of wave-energy policy research, and can reveal the dynamic development law of wave-energy policy research [27,28]. In this paper, Nvivo 12 plus was selected to analyze the current wave-energy policy text in China, sort out the content of wave-energy policy, summarize the core elements of wave-energy policy, and explore the key areas of wave-energy policy in the future [29,30].

2.3. Research Steps

2.3.1. Literature-Visualization Analysis

First, the documents retrieved from CNKI and WOS were imported into Citespace software for data conversion and de-duplication, resulting in 35 Chinese documents and 667 English documents. The second step was to establish two databases, named "WAVE ENERGY CNKI" and "WAVE ENERGY WOS." The CNKI database was set from January 1992 to December 2022; the WOS database was set from January 1996 to December 2022. The time slice was set to 1 year, and the other options were set according to the default parameters. In the third step, the node types in the two databases were set as "NodeTypes = Research Author" and "NodeTypes = Research Institution," the sample literature data were analyzed as a whole, and the scientific research subjects and scientific research cooperation were analyzed. The knowledge map that was drawn shows the overall trend in wave-energy policy research and the cooperation of scientific research subjects. In the fourth step, the node types of the two databases were adjusted to keywords for the sample literature data for keyword co-occurrence, keyword clustering, keyword emergence, timeline presentation, analysis of domestic and foreign wave-energy policy-research focus, overall research context, and research frontier. The fifth step was to change the node type of the WOS database to "Cited Reference," conduct a literature co-citation analysis for the WOS database samples, form a citation network that could be traced back to the source and development, and describe the continuity and inheritance of policy hotspots [31].

2.3.2. Visual Analysis of Policy Texts

The first step was to create a "Wave-Energy Policy" project and import the policy text into Nvivo software. Second, the word-frequency statistics function was used to search the keywords and word frequency of the policy text, focusing on the high-frequency words in the policy text. In the third step, the automatic-coding function was used for preliminary coding analysis as a reference for manual coding. The fourth step was to summarize the core categories of the current wave-energy policy based on the grounded theory and the automatic coding results. The fifth step was to compare and analyze the two key policy texts according to the different characteristics of the nodes so as to reveal the evolution trend of the policy objectives at different times.

3. Literature-Visualization Analysis

3.1. General Situation

To understand a research field, it is necessary to break down and analyze the overall situation, such as the publication time, number of publications, and publication trends, to help researchers quickly grasp the research trends in this field and pave the way for a further, in-depth understanding in stages.

3.1.1. Overall Number of Publications

The publication-trend chart was drawn based on the number of sample studies that was found in the CNKI database and WOS database (Figure 1). As shown in Figure 1, the domestic literature on wave-energy policy began to be published in 1992, earlier than the international literature on wave-energy policy, which was published starting in 1996. From the post and on the basis of an analysis of the annual average number, looking at the total domestic output over nearly 30 years, the total number of published studies equaled 35, with an annual average of 1.17. Over 26 years, the international community published 667 papers, with an annual average of 25.65. Both at home and abroad, the annual total that was identified presents an obvious gap, indicating that Chinese scholars lack interest in wave-energy policy research. The emphasis on wave-energy policy research is not enough, and this could also indicate that the wave-energy policy-system construction is not complete. An analysis from the perspective of the overall trends shows that the wave-energy policy research at home and abroad started at the end of last century. In 2004, it attracted more attention from scholars, with the international number presenting an obvious growth trend, with a faster research and development speed than the domestic total. There is still great room for improvement in the research on wave-energy policy in China.

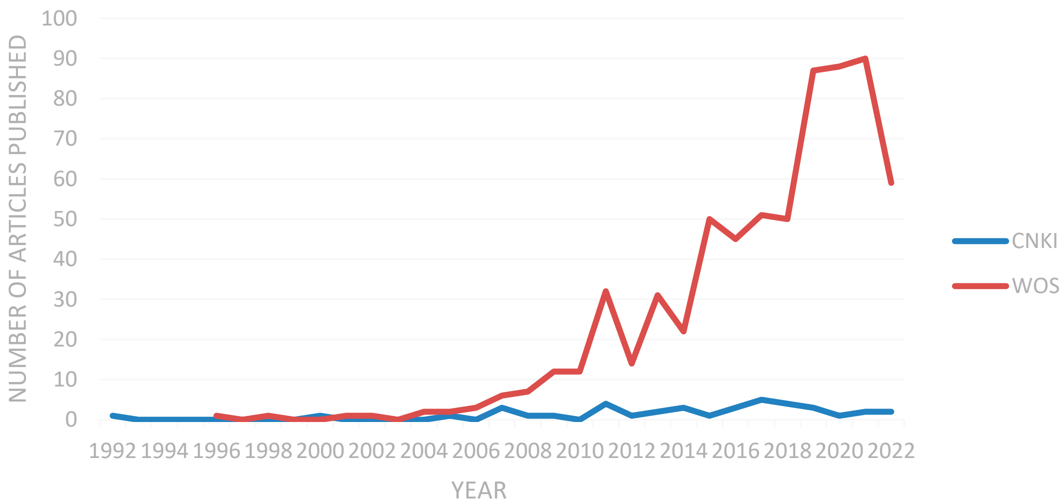

Figure 1. Annual distribution of published literature on wave-energy policy research.

3.1.2. Information about the Author and the Institution

To conduct in-depth research in a research field, one should first pay attention to the academic achievements of the core authors. According to Price's law, the number of core authors can be calculated using the following formula [32].

$$\mathrm{MP} = 0.749\sqrt{NP\max}$$

MP represents the minimum number of published papers by the core authors, and *NPmax* represents the cumulative number of published papers by the authors with the most papers within the research period. If a stable core group of authors accounts for 50% of the total number of papers, it can be considered that a core group of authors was formed in this field. The degree of cooperation between the authors of academic research is also an important index by which to judge the progress of academic research. A single author's research ability is limited, so he cannot cover all branches of the discipline, and a good scientific-research-cooperation relationship is conducive to the maturity of the discipline system.

In China, Citespace is used to visually analyze authors. From the perspective of core authors, it was found that Wang J published the most documents, with a total of four papers. According to the calculation formula, the MP value is 1.5; that is, for two or more papers, an author can be regarded as the core author in the field of wave-energy policy research in China (as shown in Table 1). According to the search for "Wang J" and "Ma CL" on CNKI, the key author Wang J focuses on the development, utilization, and industrialization of marine energy. Ma CL, the core author, focuses on technical fields such as ocean-energy generation and wave-energy development and utilization. From the perspective of author cooperation, the density value of the atlas of co-authors of domestic wave-energy policy research is 0.0399, which is lower than the normal level of 0.1. In the atlas (Figure 2), the connection is short and the density is low. Wang J, Ma CL, and Wang HF of the National Oceanographic Technology Center of the State Oceanic Administration are the leaders of wave-energy policy research. However, the authors of the overall wave-energy policy research did not form a close academic-cooperation group, which reflects that wave-energy policy researchers are relatively independent.

Table 1. Keyword co-occurrence frequency (TOP10).

CNKI			WOS		
Keyword	**Frequency**	**Earliest Publication Year**	**Keyword**	**Frequency**	**Earliest Publication Year**
Ocean energy	14	2000	Renewable energy	74	1996
Renewable energy	7	1992	Climate change	73	2008
Marine renewable energy	4	2005	Impact	70	2001
Wave energy	4	2011	Policy	61	2008
Recommendation	3	2011	Wave energy	50	2009
Industry status quo	3	2015	Energy	45	2010
Ocean	3	2011	Model	45	2011
Sea wind	2	2007	System	43	2007
Research and development	2	2007	Optimization	37	2013
Energy structure	2	2017	Management	28	2007

As shown in Figure 3, the number of nodes of domestic cooperative institutions is N = 33, the number of connections is E = 17, and the network density is D = 0.0322, indicating that only 32 domestic institutions have published articles on wave-energy policy in domestic journals, and the links between the institutions are not close. Looking at the number of published institutions (see Table 2), there is a significant gap in the number of published institutions, and the research institutions focusing on wave-energy policy are mainly concentrated in marine-research centers at the national level. Among them, the National Oceanographic Technology Research Center published 10 papers and the National Oceanographic Information Research Center published 3 papers, accounting for 37% of the total number of published papers in China. These two institutions are the backbone of wave-energy policy research.

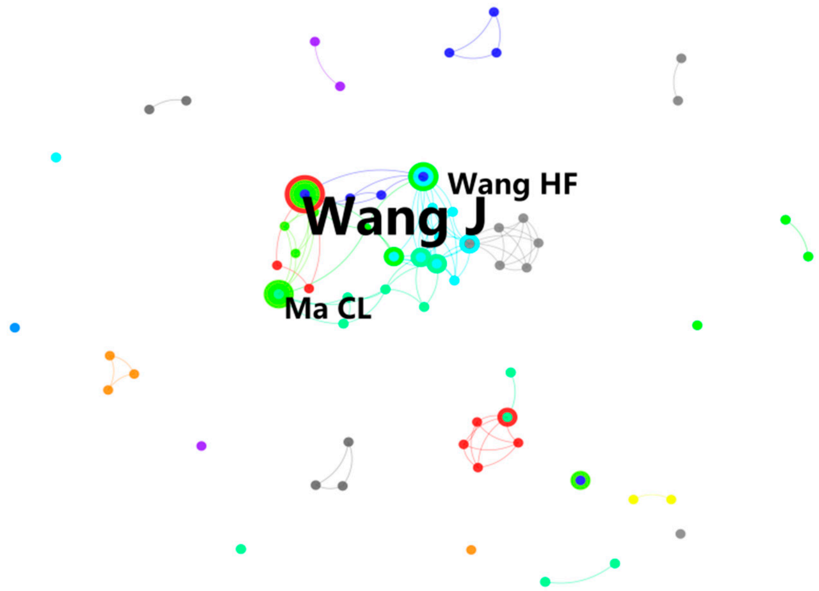

Figure 2. CNKI co-authors.

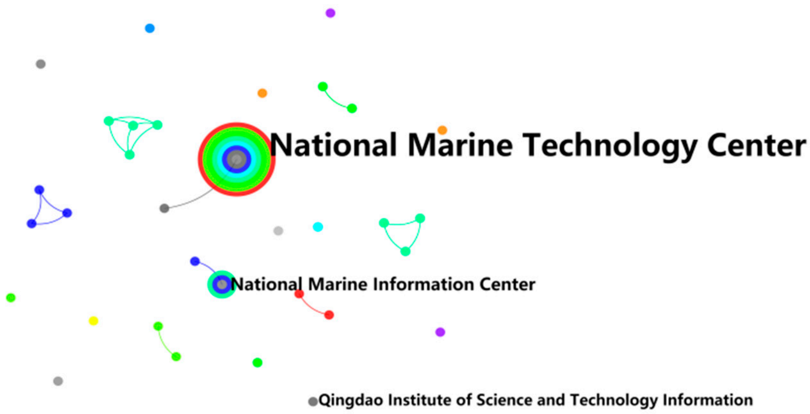

Figure 3. CNKI co-operating agency.

Table 2. WOS keywords centrality (TOP 10).

Keyword	Frequency	Centrality	Earliest Publication Year
Climate change	73	0.22	2008
Renewable energy	74	0.14	1996
Risk	14	0.13	2002
Impact	70	0.12	2001
Model	45	0.12	2011
System	43	0.12	2007
Policy	61	0.11	2008
Optimization	37	0.1	2013
Management	28	0.1	2007
Consumption	13	0.1	2018

Based on comprehensive Figures 4 and 5, high-level wave-energy policy research is lacking and the scientific research cooperation is low. A sufficient amount of attention to this issue is required to strengthen the cooperation of wave-energy policy research exchanges, share and synchronize resources and achievements, and increase the level of wave-energy policy research in our country as soon as possible.

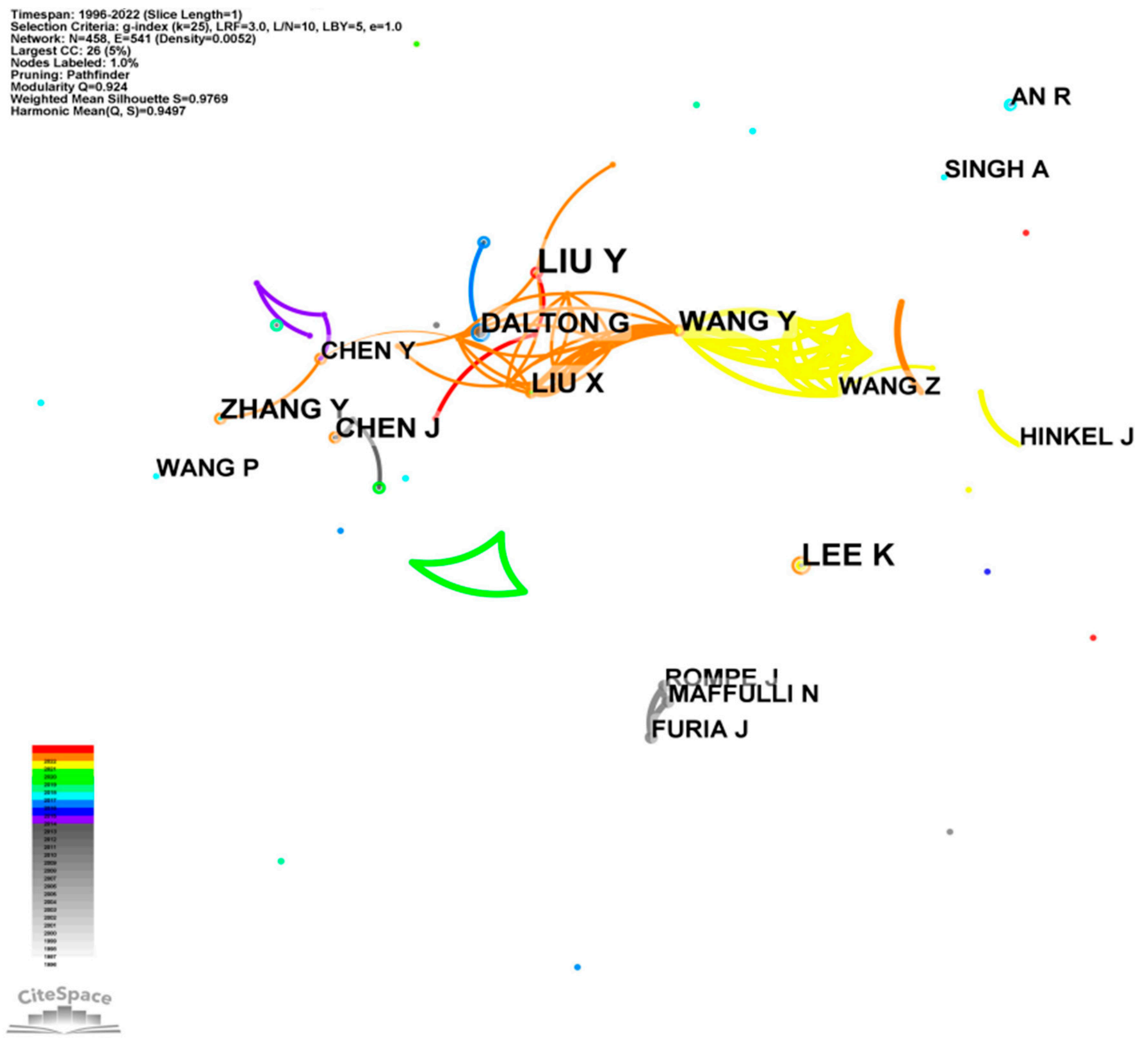

Figure 4. WOS co-authors.

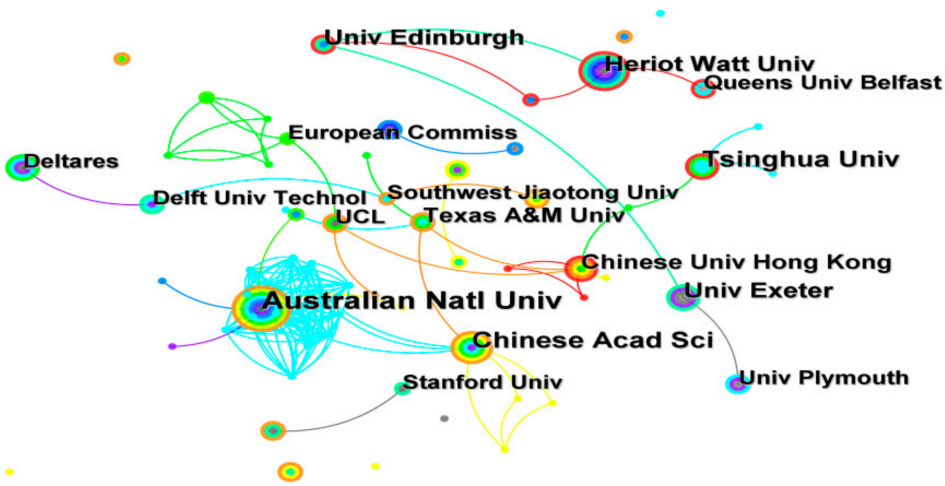

Figure 5. WOS co-operating agency.

Internationally, Liu Y is the scholar with the largest number of published literature on wave-energy policy in WOS. According to the calculation formula, the MP value is 1.83, which means that for two or more published papers, Yang can be regarded as the core author in the field of international wave-energy policy research. There are 73 core authors in the field of international policy and environmental studies. In terms of the number of articles published by institutions, Australian Natl Univ published the most papers—10—followed by the Chinese Academy of Sciences and Tsinghua University with eight papers, whereas Heriot Watt Univ, Univ Edinburgh, and Univ Exeter published seven papers each. The overall publication volume of influential international institutions is much higher than that of domestic institutions.

Citespace was used to create a visual analysis of international authors and institutions. As shown in Figure 4, the density of the map of co-authors of foreign wave-energy policy research is 0.0052 (<0.1), but the authors Liu Y, Dalton G, Wang Y, Liu X, and Wang Z obviously formed a cooperative network, which is conducive to resource-sharing and discipline integration, and promotes the deep integration of wave-energy policy research. Figure 5 shows the cooperation network of international research institutions. The number of nodes is N = 394, the connection is E = 413, the network density is D = 0.0053, and cooperation between institutions is not obvious. Australian Natl Univ, which has the largest growth rings, published the most papers and is surrounded by a dense network of connections, suggesting that the organization formed a circle of collaboration on wave-energy policy.

By comparing the number of publications published by CNKI and WOS institutions, the number of publications published by Chinese Academy of Sciences and Tsinghua University ranks second and third among WOS institutions, but no literature from these institutions can be found in the domestic CNKI database. This also indicates that Chinese wave-energy policy has not had a large-scale impact on domestic academic journals, and the next step should be to guide institutions that contribute to wave-energy policy to strengthen domestic academic cooperation.

3.2. Research Hotspots

3.2.1. Keyword Co-Occurrence Analysis

Through the CiteSpace keyword co-occurrence function, the frequency of keywords was determined, research hotspots in the wave-energy policy field were investigated, and the latest research content and research vitality in this field were judged. CiteSpace and the NodeTypes were adjusted to high-frequency keywords to obtain the keyword co-occurrence map (as shown in Figures 6 and 7) and keyword-frequency table (as shown in Table 1).

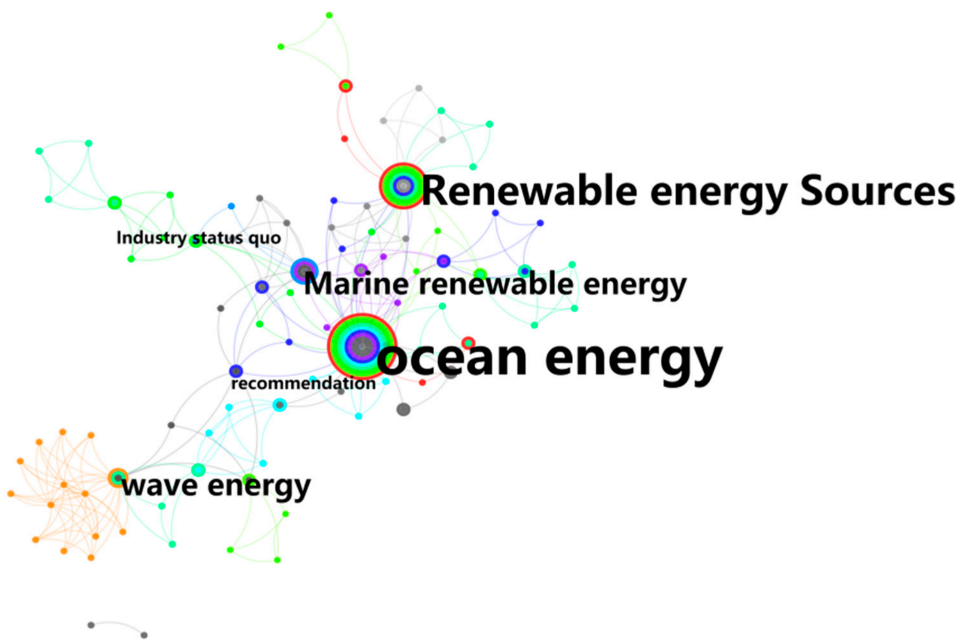

Figure 6. Keyword co-occurrence knowledge map in CNKI.

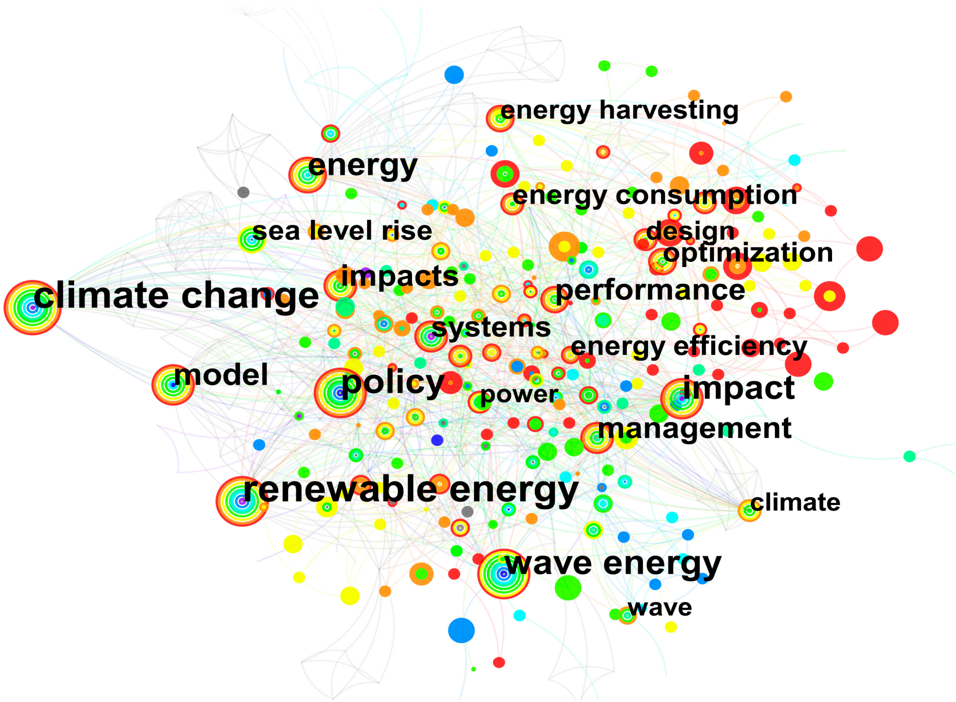

Figure 7. Keyword co-occurrence knowledge map in WOS.

As shown in Figure 6, the network density of the CNKI database keyword co-occurrence map is density = 0.0474 (N = 103, E = 249), and the size of the growth ring is proportional to the frequency of the keyword occurrence. The top five keywords are "marine energy" (14), "renewable energy" (7), "marine renewable energy" (4), "wave energy" (4), and "industrial status" (3). This shows that domestic studies on wave-energy policy mainly focus on the industry status quo, energy structure, and future development and utilization of marine renewable energy. Since China wrote wave energy as marine renewable energy into the law in 2006, it has not carried out large-scale research and development of wave-energy technology, so the research content is not in-depth.

From the frequency of keywords (Table 1), the top five keywords are "renewable energy" (74), "climate change" (73), "impact" (70), "policy" (61), and "wave energy" (50), which indicates that the international research on wave-energy policy mainly focuses on the following contents: (1) policy object: renewable energy, (2) policy background: climate change and international environmental impact, and (3) specific policy research on wave energy, such as wave-energy development assessment [33], impact of wave-energy development, technological innovation, etc. [34]. It can be seen that the international community is very optimistic about the development potential of wave energy as marine renewable energy, which is very helpful to global problems such as climate warming, sea-level rise, and energy shortage. At the same time, with the outbreak of the energy crisis, the development and utilization of renewable energy is imminent, and countries have formulated relevant policies to promote the further promotion of renewable energy.

The keyword centrality shown in Table 2 was obtained by sorting out the top 10 centrality keywords. Climate change plays the most important role in the "medium" of the keyword co-occurrence map, with a heart value as high as 0.22, risk frequency of 14 times, centrality of 0.14, consumption frequency of 13 times, and centrality of 0.1. This shows that foreign research on wave-energy policy also involves policy risk and energy consumption, and the research content covers a wide range of subjects. The high-frequency keyword "renewable energy" has been studied since 1996. The earliest years of foreign high-frequency keywords were mainly around 2007, and the earliest years of domestic high-frequency keywords were mainly around 2011. This shows that, although domestic wave-energy policies started in 1992, the research was not effectively continued until the climate problem and energy crisis became increasingly urgent in recent years. Domestic wave-energy policy research has deepened gradually, which is consistent with the overall trend of issuing documents.

The frequency of keyword co-occurrence in Figures 8 and 9 and Tables 3 and 4 shows that there are similarities in the research priorities for wave-energy policies at home and abroad, both of which focus on the development and utilization of renewable energy, especially marine energy, to improve the ecological environment. However, compared with domestic research, foreign research is more detailed in terms of policy risk, policy systems, policy management, etc. In the next step, China should further study wave-energy policies using the overall framework.

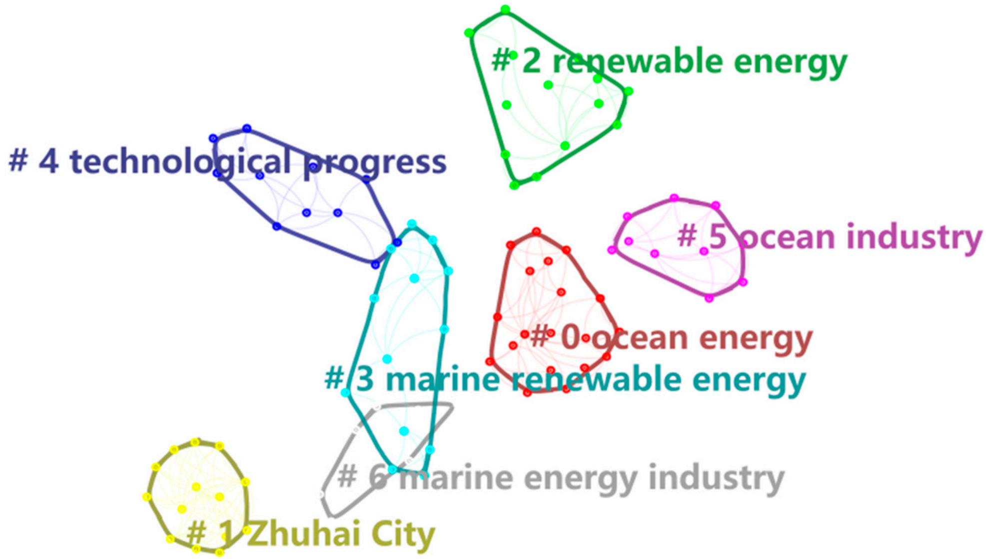

Figure 8. Keyword-clustering knowledge map in CNKI.

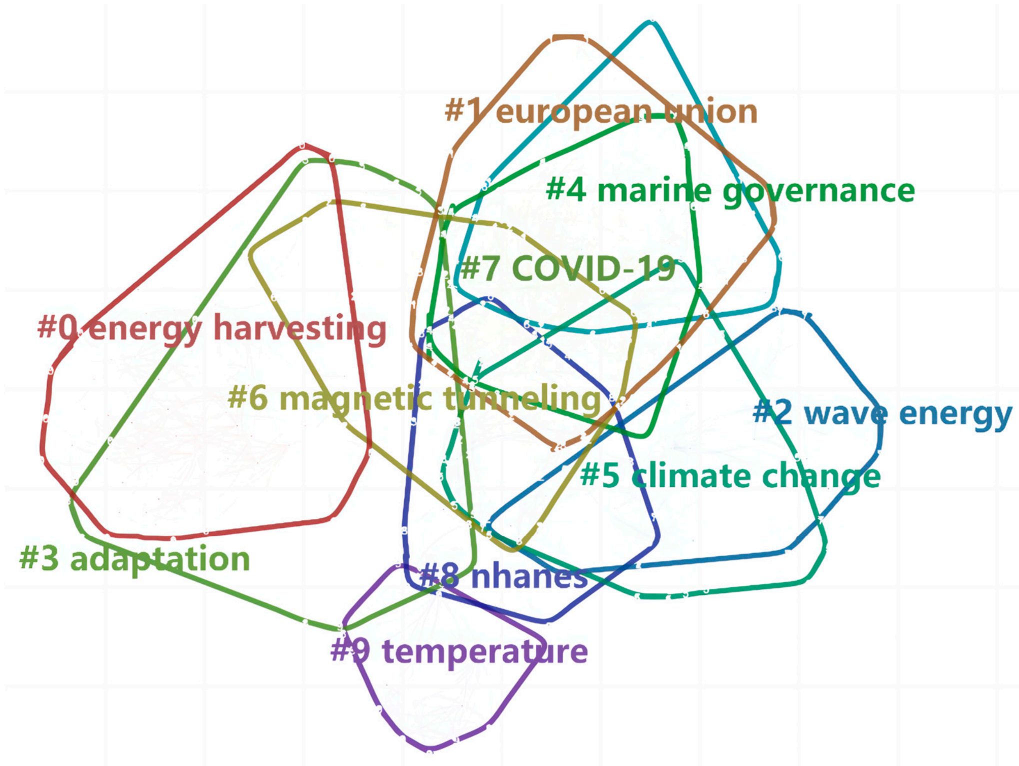

Figure 9. Keyword-clustering knowledge map in WOS.

Table 3. Basic information of highly cited literature (TOP5).

Database	Serial No.	Article	Publication	Year	Cited Quantity
CNKI	1	Strategic Choice for National Adjustment of Energy Structure	*Advances in Earth Science*	2000	118
	2	Review of marine energy research and development in China	*Ocean Development and Management*	2008	67
	3	Analysis on research and development of ocean energy in China	*Ocean Technology*	2007	61
	4	Status of domestic and international ocean renewable energy technological development and relevant suggestions	*Renewable Energy Resources*	2011	51
	5	Development status and roadmap of marine power generation technology	*Electric Power*	2018	32
WOS	1	Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials	*Energy Policy*	2011	884
	2	Marine renewable energy: potential benefits to biodiversity An urgent call for research	*Journal of Applied Ecology*	2009	280
	3	Real-World Carbon Dioxide Impacts of Traffic Congestion	*Transportation Research Record*	2008	278
	4	Urban form and climate change: Balancing adaptation and mitigation in the US and Australia	*Habitat International*	2009	257
	5	Linking emission trading to environmental innovation: Evidence from the Italian manufacturing industry	*Research Policy*	2015	205

Table 4. China's wave-energy policy documents.

Year	Policy Name	Year	Policy Name
2006	Renewable Energy Law of the People's Republic of China	2017	Action Plan for Sustainable and Healthy Development of Marine Engineering Equipment Manufacturing Industry (2017–2020)
2007	Medium- and Long-Term Development Plan of Renewable Energy	2017	Three-Year Action Plan for Enhancing the Core Competitiveness of Manufacturing Industry (2018–2020)
2007	China's National Program on Climate Change	2018	Implementation Opinions on Promoting the High-Quality Development of Marine Economy
2008	National Science and Technology Planning Outline 2008–2015	2020	Catalogue of Industries Encouraging Foreign Investment (2020 Edition)
2009	China's Marine Science and Technology Development Roadmap to 2050	2020	Statistical Investigation System of Marine Economy
2010	Interim Measures for the Administration of the Special Fund for Marine Renewable Energy	2020	Accounting System for Gross Marine Product
2010	Amendment to the Renewable Energy Law of the People's Republic of China	2021	The 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of the Long-term Goals for 2035
2011	Outline of the National 12th Five-Year Plan for Marine Science and Technology Development		
2011	National Marine Function Zoning (2011–2020)	2021	Reference Relationship between Strategic Emerging Industry Classification and International Patent Classification (2021) (Trial)
2012	Report to the 18th National Congress of the Communist Party of China		
2012	The 12th Five-Year Plan for National Economic and Social Development of the People's Republic of China	2021	Carbon Peak Action Plan by 2030
2012	The 12th Five-Year Plan for national Marine economic development	2021	Statistical Classification of Energy Conservation, Environmental Protection and Clean Industry (2021)
2013	Outline of Marine Renewable Energy Development (2013–2016)	2022	Energy Carbon Peak Carbon Neutralization Standardization Improvement Plan

Table 4. *Cont.*

Year	Policy Name	Year	Policy Name
2015	China Ocean Development Report (2015)	2022	Renewable Energy Development Plan of the "14th Five-Year Plan"
2016	Interim Measures for the Administration of the Special Fund for Marine Renewable Energy	2022	The 14th Five-Year Plan for Modern Energy System
2016	National Plan for Rejuvenating the Sea through Science and Technology (2016–2020)	2022	Notice on Preferential Policies for Enterprise Income Tax in Hengqin Guangdong Macao Deep Cooperation Zone
2016	The 13th Five-Year Plan for the Comprehensive Work of Energy Conservation and Emission Reduction		

3.2.2. Keyword-Cluster Analysis

Keyword-clustering analysis refers to the classification of keywords according to their degree of similarity so that the similarity between keywords in the same category is stronger than that of keywords in other categories. The purpose of this is to maximize the homogeneity of clustering keywords and the heterogeneity of keywords between clusters [35,36]. Through the LLR algorithm, we obtained the keyword-clustering atlas for research at home and abroad (Figures 8 and 9).

As shown in Figure 10, the keyword-clustering atlas of the CNKI database shows that the clustering module value Q = 0.7269 (>0.5) and the average contour value S = 0.9269 (>0.7) are reasonable and reliable. Seven keyword clusters were formed in domestic research, including #0 "ocean energy," #1 "Zhuhai City," #2 "renewable energy," #3 "marine renewable energy," #4 "technological progress," #5 "ocean industry," and #6 "marine energy industry." These seven clusters overlap to varying degrees. As shown in Figure 11, the keyword-clustering atlas of the WOS core-set database shows a clustering module value of Q = 0.6083 (>0.5) and an average contour value of S = 0.8281 (>0.7), suggesting reasonable clustering results and relatively high reliability. It can be seen that nine clusters were formed in foreign research, including #0 "energy harvesting," #1 "European union," #2 "wave energy," #3 "adaptation," #4 "marine governance," #5 "climate change," #6 "magnetic tunneling," #7 "COVID-19," #8 "nhanes," and #9 "temperature," and the clustering effect is clear, specifically when involving energy collection, policy subjects (EU), wave energy development, ocean governance, climate change, wave-energy development technology, and other fields.

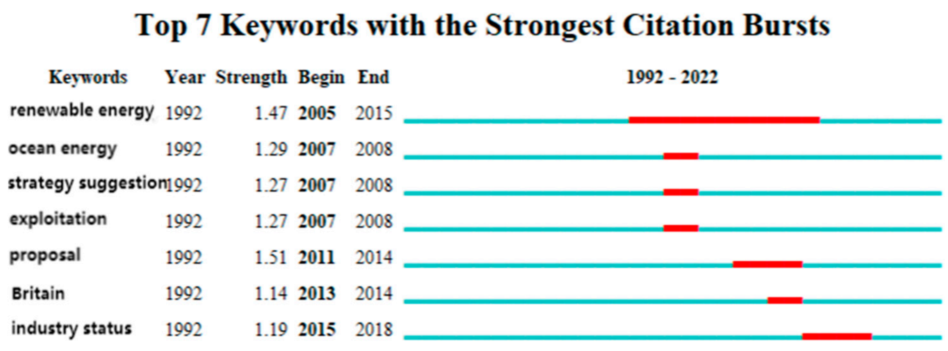

Figure 10. Keywords with the strongest citation bursts in CNKI.

Through a comparative study of keyword clustering at home and abroad, it was found that against the international background of the continuous deterioration of the ecological environment and the intensification of the energy crisis, wave-energy policy research has formed a stable theoretical research theme. The current focus is on how to effectively promote the industrialization of wave-energy development and utilization through public policies and win broad public support, and how to achieve the internationalization of wave-energy resources through the establishment of a political platform [37]. In the context of the energy transition, continued research on wave-energy policy can help countries that are developing or preparing to develop wave energy. The hot issues of wave-energy policy can also be used as the entry point to combine theory with practice. This provides a framework for building an efficient wave-energy policy.

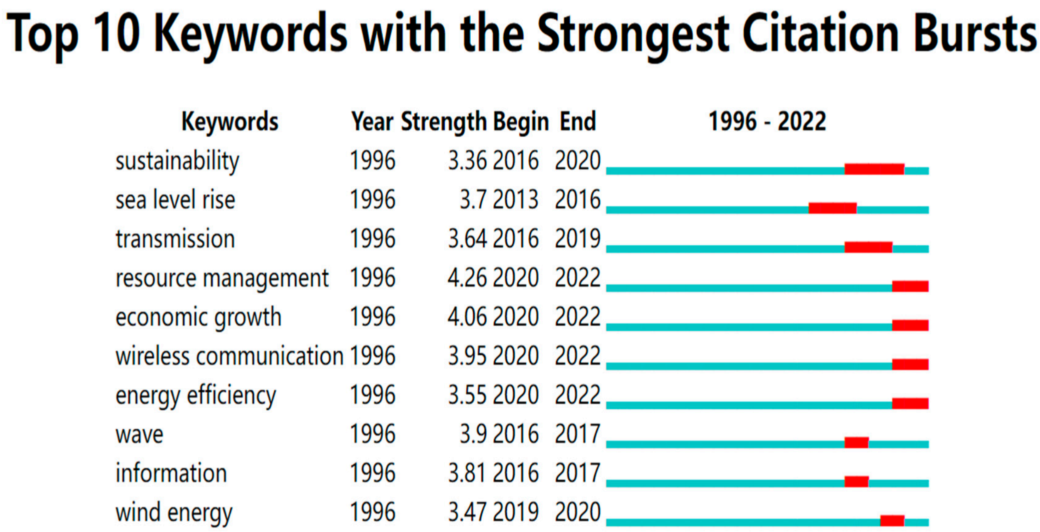

Figure 11. Keywords with the strongest citation bursts in WOS.

3.2.3. Keyword-Emergence Analysis

Emergence analysis refers to the sudden increase in the number of times a word is used within a period of time, which deserves great attention and in-depth analysis. Chen Chaomei believes that emergent words can represent the academic frontier issues in relevant fields and reflect the dynamic changes and potential trends in this field [38]. The emergent keywords are used to explore the emergent dynamic concepts and potential research problems in wave-energy policy research, and help to predict the research hotspots and trends in the future period. As the emergent state of emergent words usually shows time continuity, more attention should be paid to the continuation period if the period is 2 years or more; therefore, the burprocess function in Citespace was used for keyword emergence. There was a low number of sample studies in the CNKI database; therefore, the γ value was adjusted to 0.3, the minimum-duration parameter was set to 2, and the keyword-outburst map of the CNKI database was obtained (Figure 10). For the WOS core-set database, the default-parameter γ value was set to 1 and the minimum-duration parameter was set to 2 to obtain the keyword-outburst graph of the WOS core-set database (Figure 11). In the graph, "Strength" represents the intensity of keyword emergence, "Begin" represents a sudden increase in the frequency of use of a keyword in that year, and "End" represents a return to normal frequency of use of a keyword after this year. The blue block represents the total study period of this sample database, and the red block represents the period of a keyword's emergence.

As shown in Figure 10, the CNKI sample literature contained a total of seven prominent words. The keywords with high prominence intensity include "suggestions" (1.51), "marine renewable energy" (1.47), "marine energy" (1.29), "development research" (1.27), and "policy suggestions" (1.27), which indicate that these are frontier topics to which domestic researchers paid more attention in their corresponding time periods. As shown in Figure 11, the WOS sample literature contained a total of 10 emergent words. The keywords with high emergent intensity include "resource management" (4.26), "economic growth" (4.06), "wireless communication" (3.95), and "wave" (3.9), which indicates that these are frontier topics to which international researchers paid more attention in the corresponding time periods. From the perspective of the duration of emergence, CNKI wave-energy policy has been emerging for a long time: "marine renewable energy" (11 years), "suggestions"

(4 years), and "industrial status" (4 years). The wave-energy policies retrieved by WOS have lasted for a long time, including "sustainability" (5 years), "sea-level rise" (4 years), and "transmission" (4 years). From the time when the words first appeared, the three keywords of CNKI wave-energy policy were concentrated in 2007, when the Chinese government issued the National Plan for Climate Change, which took strict control of greenhouse-gas emissions as an important task for future development, proposed the important concept of a low-carbon economy, and prompted the Chinese government to issue a number of policies and measures for renewable-energy development to meet the needs of energy transformation [39,40]. The wave-energy-policy mutation keywords in the WOS database showed an obvious phased trend after being sorted according to time. Among them, 2013 is the first mutation time, and the keyword with the highest emergence intensity was "sea-level rise" (3.7). The main reason for this sudden emergence is that, at the end of 2012, the UN Climate Conference legally determined the second commitment period of the Kyoto Protocol, which was implemented in 2013 based on the principle of "common but differentiated responsibilities." Defining the prevention of sea-level rise as a global problem attracted extensive attention from international scholars [41]. The second intensive period for mutations was 2016. The keywords with a high emergence intensity include "wave" (3.9), "information" (3.81), "transmission" (3.64), and "sustainability" (3.36). The reason for this emergence is that the wave-energy technology of many international ocean-energy companies made breakthroughs, the development and utilization of wave energy entered on the experimental stage, and policy research showed an incentive, meticulous, and diversified trend. The year 2020 is the third mutation-intensive period. The keywords with high emergence intensity include "resource management" (4.26), "economic growth" (4.06), "wireless communication" (3.95), and "energy efficiency" (3.55). Wave-energy policy research at this stage focused more on the synergistic effect of energy transformation and economic growth, optimizing resource allocation through policy guidance and improving energy efficiency. This will also be the development direction of wave-energy policy formulation and research in the future [42].

3.2.4. Analysis of Highly Cited Literature

The most highly cited literature is the most influential literature in a certain research field. A high number of citations reflects the quality and impact of academic achievements [43]. The sample documents were ranked from high to low according to citation frequency, and documents with a low correlation with wave-energy policy were excluded. The top five most-cited documents of domestic and foreign sample documents were selected for detailed analysis (as shown in Table 3) to analyze the mainstream issues in wave-energy policy research.

From the content of the highly cited documents, the research content of highly cited documents in China is shown to mainly be limited to the surface field of marine-energy development status, mainly because wave-energy development in China is still in the experimental stage and the research was less likely to cover specific aspects such as policy implementation and evaluation [44]. The highly cited documents in the WOS database, such as the highly cited TOP1, mainly describe the feasibility, variability, and economy of taking marine renewable energy as a global energy subject and point out that the development and utilization of marine renewable energy is mainly hindered by social and political aspects, rather than economic and technological aspects [45]. TOP2 mainly describes the impact of the use of marine renewable energy on biodiversity and tries to reduce the negative impact through policy guidance [46]. TOP3 mainly explores various ways to reduce carbon emissions [47]. TOP4 mainly examines whether the current energy policy has truly and effectively improved the ecological environment [48]. TOP5 reveals the impact of policy implementation on environmental innovation [49]. The research contents of the highly cited documents of foreign wave-energy policy research included policy formulation, policy guidance, policy effects, policy evaluation, and other fields; the research contents were more extensive; and the research level was more in-depth.

3.3. Research Context

To further analyze the evolution of each keyword, the time graph generated by Citespace was used to describe the duration and development trend of hot topics in the field of wave-energy policy research. The horizontal axis represents the time axis, the right vertical column represents keyword clustering under the LLR algorithm, each node in the horizontal axis represents a research topic, the number of node circles is proportional to the frequency of the occurrence of corresponding keywords, and the lines between nodes represent the connection between different keywords.

In the keyword-evolution graph of the CNKI database, N = 103, E = 249, Q = 0.7269 > 0.5, and S = 0.9269 > 0.7; in the keyword-evolution graph of the WOS core-set database, N = 503, E = 1662, Q = 0.6.83 > 0.5, and S = 0.7014 > 0.7. The timeline division structure is, therefore, reasonable.

In the CNKI database, as shown in Figure 12, the nodes on the horizontal-axis timeline show two characteristics: first, there are more node circles in the early stage and fewer node circles in the late stage; second, the distribution of nodes in the early stage is scattered and the distribution of nodes in the late stage is concentrated, indicating that the overall research trend in wave-energy policy changed from comprehensive to refined. In the figure, only nodes with the keywords "marine energy" and "renewable energy" are obvious, whereas the other nodes are not prominent, indicating that domestic wave-energy policy-research hotspots are not prominent, policy guidance is insufficient, and the policy coverage is not complete [50]. From the perspective of the timeline evolution of the theme word "#0 'ocean energy'," combined with our country's wave-energy policy-development practice, the wave-energy policy in our country underwent an initial research-development stage, a policy-linkage stage of multi-organizations, and the construction stage of the policy system. The wave-energy policies of our country are constantly being explored to promote the development of our country's wave-energy industry and gradually increase the level of ocean-energy technology through policy guidance. With the support of relevant policies, the development and utilization of wave energy has entered a rapid development period [40].

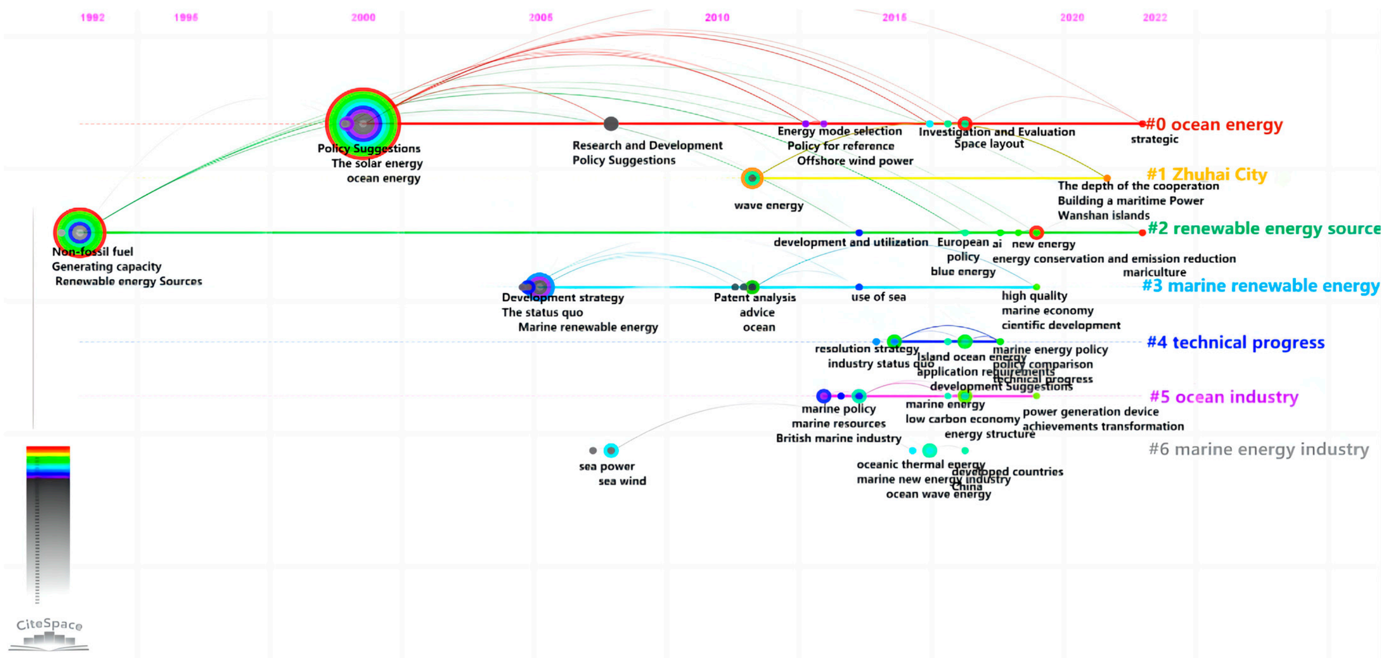

Figure 12. Knowledge map of wave-energy policy timeline in CNKI.

Figure 13 shows that foreign wave-energy policy research can be roughly divided into three stages. The first stage is the preliminary exploration stage, from approximately 1996 to 2004. In this research stage, the number of nodes is small, but the nodes are prominent. Taking the node "renewable energy" in cluster #2 and "impact" in cluster #7 as symbols, the research focus of this stage should be the initial exploration of wave energy as renewable energy and the background of policy generation. The second stage is the substantial progress stage, from approximately 2005 to 2012. In this research stage, the number of nodes increases, and important nodes are prominent. "Wave energy" in cluster #2, "system" in cluster #3, "policy" in cluster #4, "climate change" in cluster #5, "model" in cluster #6, "management" in cluster #7, and "energy" in cluster #8 are hotspots. These hotspots are closely connected with each other, indicating that international scholars carried out a series of studies on these hot topics. The third stage is the comprehensive deepening stage, from approximately 2013 to 2022. In this research stage, the number of nodes surges, mainly focused on the time axis of cluster #0, cluster #1, cluster #2, cluster #3, and cluster #4. Based on the breakthrough in wave-energy technology, the research in this stage focuses on resource integration, resource allocation, energy capture, energy consumption, and other aspects to promote the comprehensive construction of a wave-energy policy system [51]. For further analysis, the largest cluster #0, "energy harvesting" (Figure 14), and the longest timeline cluster #2, "wave-energy harvesting" (Figure 15), were included. Cluster #0, "energy harvesting," appeared for the first time in 2013, and important nodes include "optimization" (37, 2013), "energy harvesting" (19, 2016), "resource allocation" (16, 2018), and "resource management" (14, 2020). The number on the left of the brackets represents the cumulative occurrence times of keywords, and the year on the right represents the year of keyword emergence. By extracting the annual distribution map of keywords, important keywords in cluster #0 are shown to be on the rise, showing the key field for future research. Cluster #2, "wave energy," appeared for the first time in 1996, and the keyword "renewable energy" was used in the initial research, indicating that foreign wave-energy policy-system frameworks take renewable energy as the starting point, and important nodes include "renewable energy" (74, 1996), "wave energy" (50, 2009), and "performance" (25, 2015). This clustering research has lasted for more than 20 years. The annual distribution map of keywords shows that the keywords "renewable energy" and "performance" show a downward trend, whereas "wave energy" shows a slight upward trend, indicating that wave-energy policy research will remain a hot topic in the future.

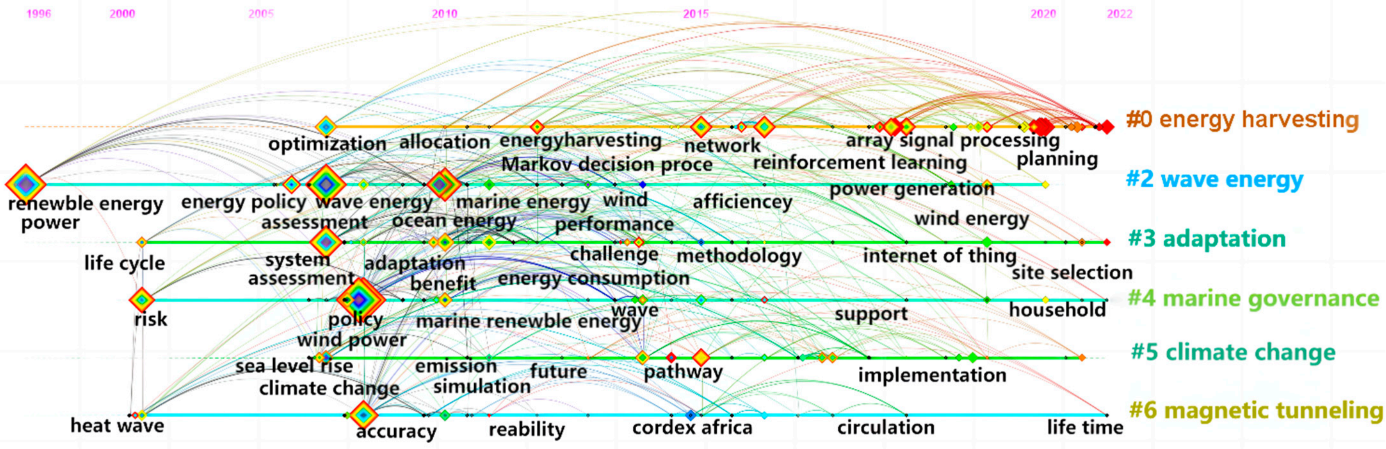

Figure 13. Knowledge map of wave-energy policy timeline in WOS.

In this paper, the literature on wave-energy policy in the CNKI database and the WOS core collection was visualized and analyzed by Citespace. From the perspective of literature publication, policy hotspots, and policy-development context, it can be seen that the overall quantity and quality of wave-energy policy research are on the rise. However, there is still a significant difference between domestic and foreign development speed. Compared with domestic wave-energy policy research, foreign countries have shown a certain cooperation network and domestic and foreign research hotspots have a certain convergence, but the domestic hotspot scope is relatively narrow and there is still room for expansion. Therefore, this study needs to further analyze the textual content of domestic wave-energy policies, explore the policy orientation at the national level, form an interactive effect from policy implementation and theoretical research, and effectively solve the practical problems in the development and utilization of wave energy.

Figure 14. Timeline of cluster #0, "energy harvesting."

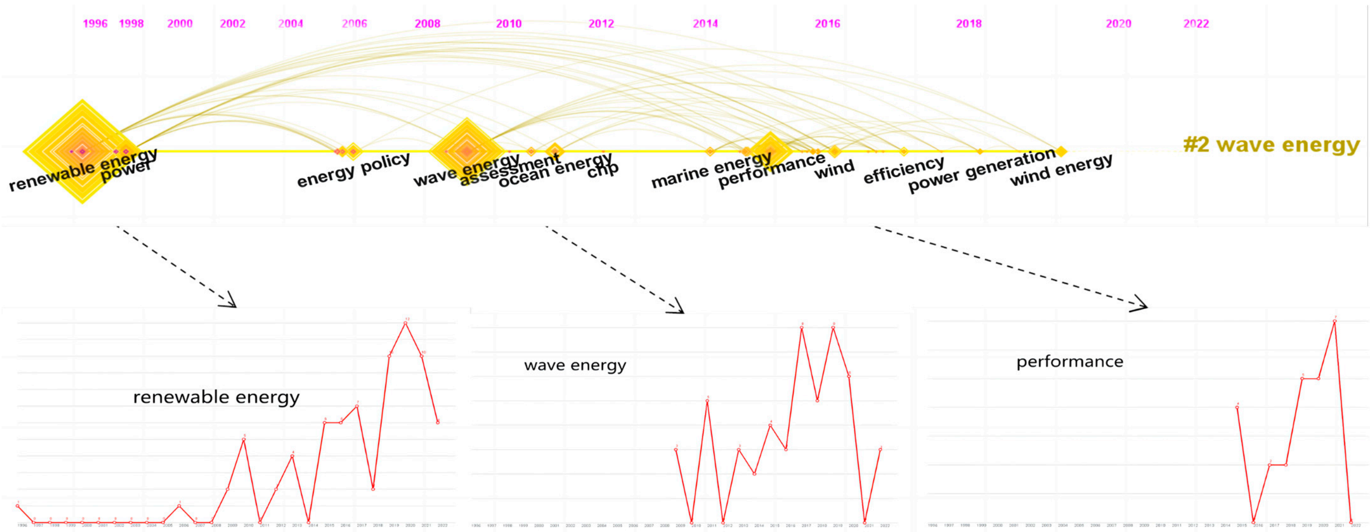

Figure 15. Timeline of cluster #2, "wave energy."

4. Visual Analysis of China's Wave-Energy Policy Text

4.1. Policy-Development Trend

Policies are action guidelines formulated by the state or a political party to determine the rules of a certain historical period. The text forms include planning, opinions, notices, minutes, decisions, etc. [52]. After sorting out 31 policy texts related to wave energy, as shown in Table 4, wave-energy policies were mainly shown to express China's wave-energy action guidelines in various periods in the form of legislation, systems, planning, outlines, action plans, implementation (work) plans, etc. From legislation to action plans and implementation plans, the wave-energy policy system in China was gradually systematized and integrated from point to line, and then expanded to cover a particular area.

The wave-energy policy was analyzed vertically in chronological order, and the overall change trend is shown in Figure 16. China promulgated the Renewable Energy Law of the People's Republic of China in 2006, which defined the positioning of wave energy as a renewable energy in the form of legislation. After that, the overall number of policies was not high. After 2020, the government's attention to wave energy gradually increased, consistent with the trend of wave-energy policy research. The yellow trend line shows that the number of wave-energy policy texts has an overall upward trend, and it is predicted that the next few years will be the peak period for wave-energy policy promulgation.

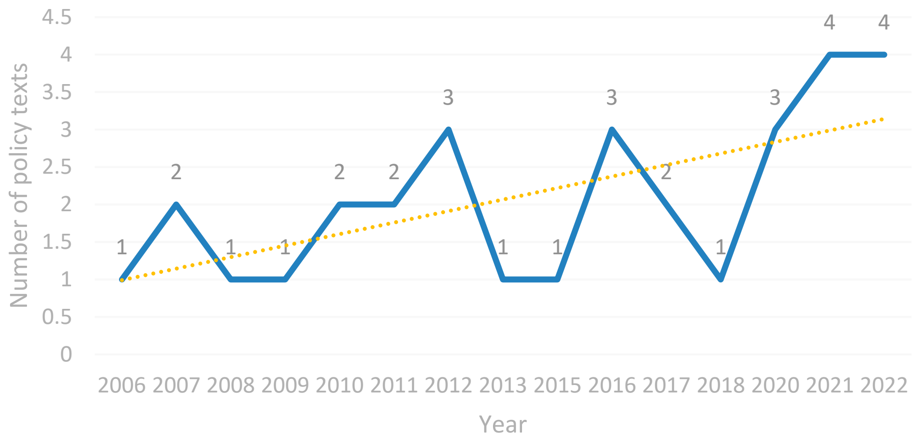

Figure 16. Trend chart of wave-energy policy-text quantity.

4.2. Word-Frequency Analysis of Policy Content

The keywords in the policy text represent the core content of the policy. The high-frequency words in the policy text were grouped by synonyms through Nvivo 12 plus. According to the Chinese custom, the word with the minimum length is defined as "2." The words with the top 100 frequencies were selected to form a word cloud (Figure 17). The font size in the figure is proportional to the number of keywords. It can be seen that, excluding the theme words "energy" and "ocean," "development," "technology," "exploitation," "build," "utilize," and "regenerate" appeared most frequently. The core content of wave-energy policies is mainly focused on the overall development and utilization, improvements in technology and equipment, and wave-energy-project construction management.

Figure 17. Wave-energy policy-text word-cloud map.

4.3. Analysis of Policy-Text Coding

Since we have not issued a single policy document on wave energy, most of the relevant policy texts take renewable energy or marine energy as their object, meaning that the effect of automatic coding through Nvivo was not good. A theoretical paradigm was used based on a grounded theory from the bottom up, using an Nvivo text search to find relevant wave-energy policies in the text according to sentence decomposition. Preliminary conceptual open coding was obtained, and the related concepts were used to establish relations with the generic spindle-type code [53]. This further summarizes the core category-choice type code. As can be seen from Table 5, there were five first-level coding nodes, forming five core elements of wave-energy policy: "basic framework" (6), "development planning" (57), "safeguard measures" (18), "technological innovation" (23), and "open cooperation" (6) (the number of reference points corresponding to the first-level coding in parentheses), with 21 second-level coding nodes and 44 child nodes, for a total of 31 policy texts involving 11 reference points. According to the visualization analysis based on the proportion of the number of reference points of first-level coding (Figure 18), the number of policy texts for development planning was the largest, accounting for 52%, followed by the number of policy texts for promoting wave-energy technological innovation, accounting for 21%. These five core elements basically constitute the wave-energy policy-framework system. Future policies should focus on ensuring the exploitation and utilization of wave energy and promoting open cooperation in wave energy [36] by improving the manufacturing level of Chinese wave-energy equipment through technological innovation, and by strengthening the discourse power of global energy governance with the interface of the global energy-cooperation system [54]. We should fulfill our responsibilities as a major country and open up new prospects for international win–win cooperation.

Table 5. Wave-energy policy-coding node.

Selective Coding	Spindle-Type Coding	Open Coding	Files	Reference Point
Safeguards	Policy support	Policy incentives	2	3
		Policy guidance	1	1
	Financial support	Financial system	1	5
		Guaranteed acquisition of renewable-energy power generation	1	1
		Tax preference	1	1
		Government investment	3	3
		Special fund	1	3
	Institutional setup	Institutional setup	1	1
Technological innovation	Technical support	Adapting to natural island environment	1	1
	Cost savings	Cost savings	1	1
	Engineering of energy-utilization technology	Productization of marine-energy development	1	1
		Expanding the application field of ocean-energy technology	1	1
	New product development	Developing equipment to realize engineering and industrial applications	4	5
	R&D and design level	Power-generation technology	4	5
		Breaking through the core technology of wave-energy development equipment	6	8
		Total installed capacity	1	1

Table 5. *Cont.*

Selective Coding	Spindle-Type Coding	Open Coding	Files	Reference Point
Open cooperation	International cooperation	Actively participating in international affairs	1	1
		Global ocean governance	1	1
		Cooperative operation	1	1
	Technology import	technology import	2	2
	Broadening financing channels	Attracting foreign investment	1	1
Development planning	Industrial integration	Wave-power supply	1	1
		Multi-energy complementation	3	4
		Mariculture	1	1
	Development environment	Development basis	2	3
		Development disadvantage	2	5
		Development trend	4	4
		Development advantages	1	1
		International development status	2	5
		Defining the types of marine renewable energy	1	2
		Site investigation and resource evaluation	2	2
	Development goals	Generation target	2	3
		Total energy target	2	2
	Development significance	Improving marine ecological environment	1	1
		Marine economic strategy	2	2
		Promoting energy conservation and emissions reduction in marine industry to	1	1
		optimize the energy structure	4	7
	Demonstration development	Demonstration development	6	10
	Optimizing layout	Marine-industry layout	1	1
		Ocean spatial layout	1	3
		Marine regional layout	4	4
Basic framework	Marine-function zoning	Marine-function zoning	1	1
	Basic connotation	Basic connotation	2	2
	Statistical standards	Statistical standards	2	3

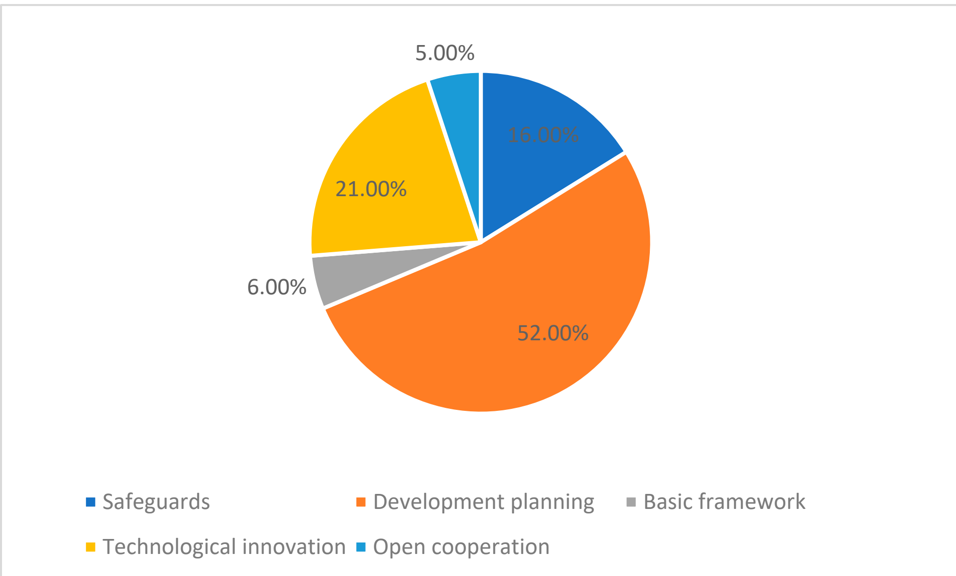

Figure 18. Distribution of the core elements of Chinese wave-energy policy text.

4.4. Comparative Analysis of Key Policies

This paper reviews the development of wave-energy policy. China has issued two important medium- and long-term development plans for renewable energy. One is the Medium- and Long-Term Development Plan for Renewable Energy, which was issued in 2007. The other is the 14th Five-Year Plan for Renewable Energy Development, which will be issued in 2022. By comparing these two policy points, the overall evolution trends in wave-energy policy can be determined. As can be seen from Figure 19, the Medium- and Long-Term Development Plan for Renewable Energy issued in 2007 initially formed a wave-energy policy framework, which established the current development environment [55]. The disadvantages of the current developments are high development costs [56], the complex marine-development environment and the relatively weak current technology level [35], and the impact of the international situation and other general policies. The main policy objectives of the 14th Five-Year Plan for Renewable Energy Development issued in 2022 include the following aspects. First, the comprehensive development and utilization of wave energy [36] aims to achieve effective energy complementarity and the operation of the ocean-industry chain. Second, China should make full use of the energy advantage of wave energy at key nodes [37] to achieve industrial integration development. Third, wave-energy demonstration-development projects should be applied enough to optimize regional energy distribution [8]. Fourth is the development of specific wave-energy promotion targets [57]. The development of wave energy should be promoted according to local conditions, and the regional distribution of energy should be optimized [58]. These establish clear and specific wave-energy promotion targets. Compared with the Medium- and Long-Term Development Plan for Renewable Energy issued in 2007, the policy instruments are diversified and the policy objectives are specific, which reflects the gradual optimization of the wave-energy policy tools and the gradual deepening of the policy intensity, and also provides local governments and various energy enterprises a clear policy signal to promote wave energy.

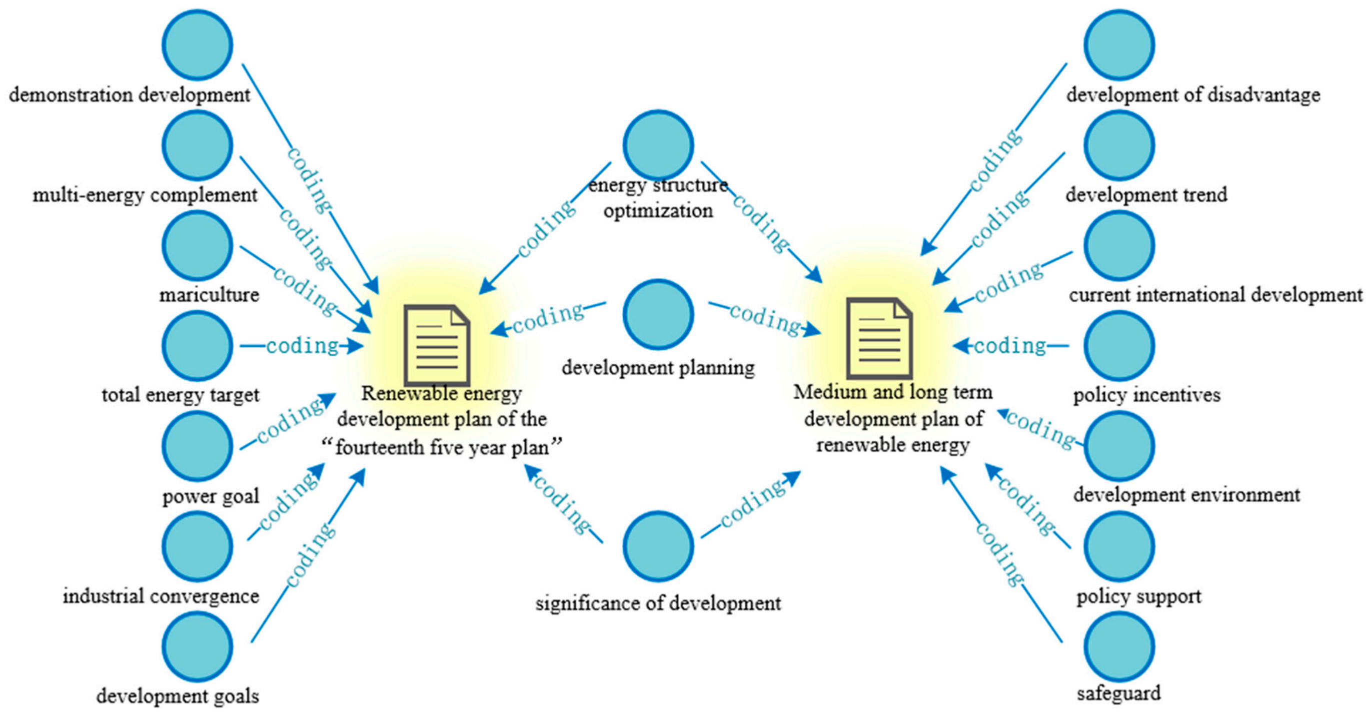

Figure 19. Comparison of nodes of renewable-energy development planning.

5. Conclusions

This paper visually analyzed the relevant literature on wave-energy policy and the texts on wave-energy policy in China from the CNKI and WOS databases based on bibliometric software. The main research conclusions are shown in the table below (Table 6).

Table 6. Research conclusions.

Research Content	Research Conclusions
General overview	The quantity and development speed of wave-energy policy research in China are lower than those around the world.
	The number of core authors in the field of wave-energy policy research in China is small, and there are obvious weaknesses in scientific research cooperation.
Research hotspot	Wave-energy policy research has formed a stable theoretical research theme.
	Both domestic and foreign studies on wave-energy policy aim at improving the ecological environment, but foreign studies are more detailed in terms of policy risks, policy systems, and policy management than domestic studies.
	The change in hot spots of wave-energy policy research in China takes 2007 as the main demarcation point. International hot spots of wave-energy policy research show obvious stages, with 2013, 2016, and 2020 as the cutoff points.
Research vein	China's wave-energy policy has gone through the initial stage of research and development, and now it has entered a period of rapid development.
	Foreign wave-energy policy research can be roughly divided into three stages. The first stage is from 1996 to 2004, when wave energy entered the initial exploration stage. The second stage is from 2005 to 2012, when wave-energy policy was rapidly promoted. The third stage is from 2013 to 2022, when the focus of wave-energy research shifted to resource integration and other aspects.
Policy text	The number of Chinese wave-energy policy texts is on the rise as a whole, with policy content gradually being refined, policy tools gradually being optimized, and policy intensity gradually being deepened.

Focusing on the quantity of wave-energy policy research, we found that the amount of research on wave-energy policies has shown an upward trend. However, there is still a significant gap between the number of foreign and domestic policy studies that are published, in terms of both the total and average annual number. Therefore, Chinese scholars should pay more attention to wave-energy policy research; strengthen scientific-research exchange; establish complementary cooperative relations between countries, regions and institutions; and continuously boost the rapid development of wave-energy policy research in China.

Looking at the content of wave-energy policy research, a stable research theme was established, both domestic and foreign. This theme mainly includes how to effectively promote the industrialization of wave-energy development and utilization through public policies, how to use the economy to win widespread public support, how to achieve the internationalization of wave-energy resources through the establishment of political platforms, etc. However, foreign research in policy risks, policy systems, policy management, and other aspects has more advantages.

Looking at wave-energy policy texts, after promulgating the Renewable Energy Law of the People's Republic of China in 2006, the Chinese government did not pay enough attention to wave-energy development. The scale of policies was small at that time. After 2020, the number of policies significantly increased, policy tools became diversified, policy content was gradually refined, and policy points were gradually concentrated in fields focusing on the overall development and utilization, technical-equipment improvements, and wave-energy-project construction management. It can be seen that China's wave-energy development started late. There were not enough policies to support the further development and utilization of wave energy. At present, China has taken maritime power as a strategic development goal; therefore, it is necessary to improve the wave-energy policy system as soon as possible to promote the rapid development of marine energy.

After combing and researching wave-energy policies, this paper believes that future research should focus on the following aspects:

In terms of policy research, cooperation between authors and institutions worldwide should be further strengthened to form a cooperative research network. Through international research cooperation, the government should enhance the study on policies, theories, and measures that are introduced in line with the national conditions of each country, especially driving studies on wave-energy policy that are in accordance with the national conditions of the country and the overall interest of the world.

Regarding policymaking, the government should reference policy guidelines and research frontiers from countries and regions with advanced wave-energy technology, then innovate localized policy practices. First of all, due to the particularity of the political system, the Chinese government should not just copy the policies of other countries entirely: reasonable policy guarantees need to be formulated for the commercial development of China's wave energy. Secondly, against the background of multiple marine resources that are developing simultaneously, the policy system is not yet perfect. Therefore, it is necessary to learn from foreign-policy experience and accelerate the formulation of policies on marine-resource management to avoid delays in marine-energy development caused by competition for marine resources. Finally, we should strengthen quantitative risk management in the development and utilization of marine energy and attach importance to the impact of possible changes in the marine environment, marine-energy utilization, and marine-energy technology development. Taking marine ecological protection as the starting point, the Chinese government should create policy guarantees for the large-scale promotion of wave energy.

6. Contributions

This article contributes in the following ways:

- Identifies the current state of cooperation in the area of wave-energy policy and the most productive institutions and individuals;
- Identifies major research topics in the area of wave-energy policy;
- Discusses the turning point of wave-energy policy evolution;
- Points out the weakness of China's wave-energy policy;
- Clarifies the direction of wave-energy policy formulation in the future.

Author Contributions: M.Q., J.L. and B.L. designed the study and wrote the paper; M.Q. and B.L. supervised the paper writing; X.D., B.Z. and B.L. collected and collated materials and undertook field-data collection. All authors have read and agreed to the published version of the manuscript.

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